

SECTION 2

PHYSIOGRAPHY, GEOLOGY AND HYDROGEOLOGY OF BERKELEY LAB

2.1 PHYSIOGRAPHY AND SURFACE WATER HYDROLOGY

The physiography at Berkeley Lab is dominated by steep west and southwest-facing slopes that have been modified by erosion of stream canyons, by mobilization of landslides, and by cut and fill operations associated with construction of the Berkeley Lab facilities. Berkeley Lab lies within the upper portion of the Strawberry Creek watershed, which consists of approximately 874 acres of land east of the UC Berkeley campus. The entire Strawberry Creek watershed occupies approximately 1,163 acres, and includes other UC properties, public streets of both Oakland and Berkeley, and private property. In the vicinity of Berkeley Lab, the Strawberry Creek watershed is subdivided into the Blackberry Canyon and Strawberry Canyon watersheds. The tributaries feeding North Fork Strawberry Creek, which flows in Blackberry Canyon, have been altered by extensive surface grading and fill placement during past building construction activities. Hence, surface water from these tributaries is collected and conveyed through reinforced concrete pipes. Both Strawberry Creek and North Fork Strawberry Creek are perennial and are fed by springs during the summer.

2.2 GEOLOGY AND HYDROGEOLOGY

2.2.1 Geologic Units

The geology and hydrogeology at Berkeley Lab are described in detail in the Draft Final RFI Report (Berkeley Lab 2000). A geologic map of the area discussed in this report is provided in **Appendix I (Figure I-1)**.

Bedrock at Berkeley Lab consists primarily of Cretaceous and Miocene sedimentary and volcanic units. These units form a northeast-dipping, faulted homocline, which underlies most of the

facility, and has been disrupted in places by ancient and modern landslides. From the structurally lowest to structurally highest units, the homocline includes the Great Valley Group, the Orinda Formation, and the Moraga Formation. The Great Valley Group and Orinda Formation consist of mudstones and fine- to medium-grained sandstones. The Moraga Formation is a resistant ridge-forming unit that is composed primarily of andesitic volcanic rocks that are typically highly fractured, jointed, and brecciated. At the base of several bodies of Moraga Formation, volcanic rocks are interleaved with siltstones, tuffs, and sandstones immediately above the underlying contact with the Orinda Formation. This zone has been informally named the Mixed Unit. Outcrops of both the Moraga Formation and Mixed Unit at Berkeley Lab appear to have been emplaced as ancient landslides that predated the present topography.

Most of the developed portion of Berkeley Lab is underlain by the Orinda or Moraga Formation. In the easternmost portion of Berkeley Lab, the homocline is disrupted by the north-striking Wildcat and East Canyon Faults. The area to the east of these faults is underlain by Miocene marine sedimentary rocks of the Claremont Formation and rocks interpreted to belong to the San Pablo Group. At Berkeley Lab's western property boundary, the homocline is truncated by the north-northwest striking Hayward Fault, a regionally extensive, active, right-lateral strike-slip fault. Rocks west of the Hayward fault consist of the Jurassic to Cretaceous Franciscan Complex.

Surficial geologic units at Berkeley Lab consist primarily of artificial fill, colluvium, and landslide deposits. The soil profile developed on the bedrock is typically a moderately to highly expansive silty clay less than 2 feet thick. Colluvial deposits, which are loose masses of soil material and/or rock fragments, are generally found along the bases of slopes and in hillside concavities.

The overall geometry of both the bedrock and surficial units in the portion of Berkeley Lab described in this report is shown on the geologic map (**Appendix I, Figure I-1**) and in hydrogeologic cross sections A-A' through F-F' (**Appendix I, Figures I-2 through I-7**).

2.2.2 Hydrogeologic Characteristics and Groundwater Yield

The hydrogeological characteristics of the bedrock units and surficial materials, along with the physiography of the site, are the primary factors controlling groundwater flow and

contaminant transport. Groundwater generally flows in a downslope direction relative to the surface topography, with westward groundwater flow in the western portion of Berkeley Lab and southward elsewhere. However, at some locations flow directions deviate from this pattern due to contrasts in the subsurface geology or man-made features such as building subdrains.

There are several bedrock geologic units in the areas of Berkeley Lab where groundwater contamination is present. The primary bedrock unit in these areas is the Orinda Formation, consisting of sedimentary rocks that dip moderately toward the northeast. Overlying this unit in most areas of the site are colluvium, artificial fill, and/or isolated masses of Moraga formation volcanic rock that are interpreted to be paleolandslide (ancient landslide) deposits. Each of these geologic units consists of a distinct assemblage of soil and rock types with its own characteristic hydrogeologic properties. Due to the complex structural geometry of these units, the hydrogeology at Berkeley Lab is characterized by a number of discrete, relatively permeable zones (primarily Moraga Formation and some surficial units), where groundwater flow is relatively rapid, separated and underlain by broad areas where underlying relatively impermeable rocks (i.e., primarily the Orinda Formation) inhibit flow. As a result of this geometry, most of the contaminated groundwater plumes at Berkeley Lab are also discrete, and do not interact hydrologically.

At least one of the three structurally lowest geologic units (rocks of the Great Valley Group, Orinda Formation and Mixed Unit) lies either at the surface or at depth beneath all of Berkeley Lab, and with few exceptions these units consist of fine-grained rock types with very low permeabilities. Well yields in these units are substantially lower than 200 gpd with the exception of a few locations where coarser-grained strata (e.g., sandstone, conglomerate) are present. Many wells installed into these units take a day or more to recharge after water stored in the well is removed.

In a number of locations, structurally and stratigraphically higher units (Moraga Formation, colluvium and artificial fill), generally with higher permeabilities, overlie the deeper units. The contacts between the lower units and upper units are highly undulatory surfaces, so that the upper units generally occupy bowl-shaped depressions in the upper bounding surface of the lower units. The Moraga Formation is relatively permeable, and therefore can produce more than 200 gpd in most areas where the water table lies within or above it. Wells screened entirely

in the Moraga Formation were generally not tested because it is assumed that they can yield more than 200 gpd. In locations where the water table lies within colluvium or artificial fill, well yields depend on the properties of these units, which differ from location to location. A geologic map constructed at the water table lowstand (i.e., the seasonal lowest dry-season water table elevation) was constructed to illustrate where these units were present in the saturated zone (**Appendix I, Figure I-8**). This map primarily used groundwater elevation data collected during September and October 1999, prior to installation and operation of most groundwater extraction systems. In a few locations, data from other years (ranging from 1993 to 2003) were utilized either because the 1999 data were not representative (i.e., water levels had been perturbed due to pumping) or because wells in some areas had not been constructed until later.

As discussed in Section 3.2.2, a sustained yield of 200 gallons per day is one of the threshold criteria used by SWRCB for determining whether groundwater is considered a potential drinking water source. Short-term pumping tests were therefore conducted in selected groundwater monitoring wells and temporary groundwater sampling points located in areas of groundwater contamination to determine which areas would not constitute a potential drinking water source (i.e., could not yield 200 gallons per day [gpd]) by this criteria. Results of the testing are tabulated in **Appendix G. Figure. 2.2-1** shows areas of groundwater contamination exceeding Maximum Contaminant Levels (MCLs) for drinking water. These areas are divided into subareas that do not constitute potential sources of drinking water and areas that may constitute potential sources of drinking water (based on the short-term yield testing results and the distribution of permeable rock units below the water table). A map showing both the water table geology and these subareas of the groundwater plumes is shown in **Appendix I, Figure I-9**. Most of the well yield testing was conducted in March 2004, when groundwater elevations are at their highest annual levels and well yields are at a maximum. During the summer and fall when groundwater elevations decline, it is likely that additional wells would have yields less than 200 gpd, particularly in those areas where the water table drops into the less permeable horizons below the base of the Moraga formation. In addition, since only short-term tests were conducted, conclusions regarding which areas may constitute potential drinking water sources are considered conservative, because longer-term tests may show that sustainable yields are less than 200 gallons per day in areas where the short-term tests showed higher yields.